From small-scale turbulence to large-scale convection: a unified scale-adaptive EDMF parameterization

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Shedding light on the greyzone

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Design of a unified parameterization

Eddy-Diffusivity/Mass-Flux (EDMF) model for turbulence

- Decomposition of subgrid domain into multiple convective thermals and non-convective environment
- Assumptions for subgrid-scale variability: joint-normal for the environment and uniform for individual thermals
- All type of thermals (dry, moist shallow and moist precipitating) represented by stochastic multi-plume model
- Turbulence in non-convective environment modeled by a local by tke-based Eddy-diffusivity approach

Macrophysics:

- Environment: PDF-based condensation (joint-normal distribution)
- Plumes: zero-or-one condensation

Microphysics:

- Environment: Analytical integration of microphysical transfer terms over the PDF
- Plumes: Same microphysical transfer terms, applied for thermals

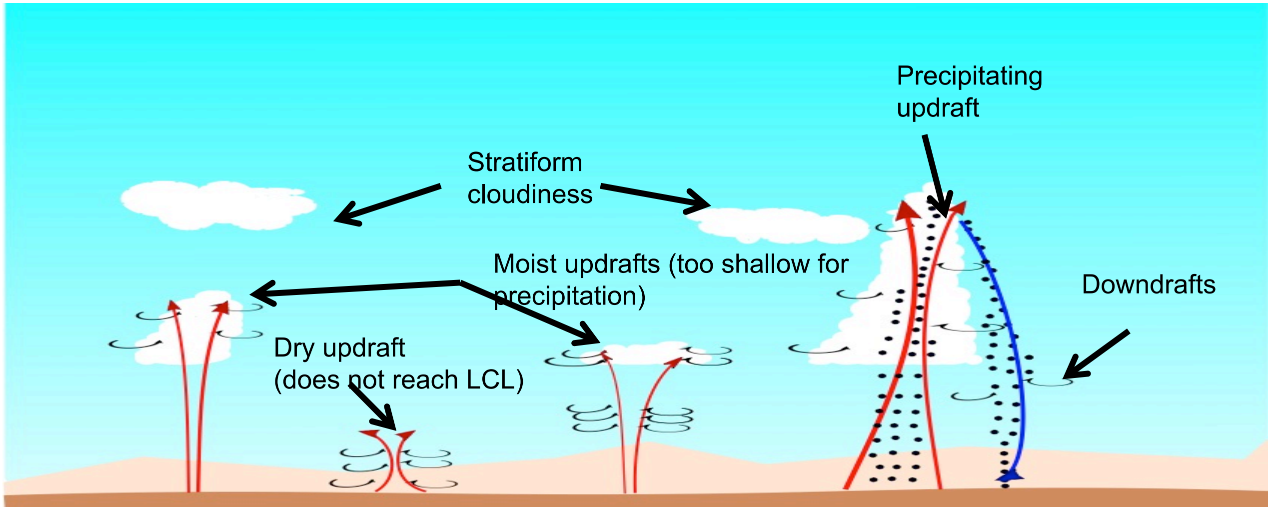
Radiation:

- Assumes same PDFs as in turbulence and microphysics

EDMF turbulence model

EDMF approach: decomposition of model's vertical column into:

- **Convective plumes (updrafts and downdrafts) - Mass-Flux (MF)**
- **Non convective environment - Eddy-Diffusivity (ED)**



Suselj et al. (2012, 2013, 2017a) – Dry and Shallow Moist Convection:

- **Multiple Plumes**
- **Plumes 'start' from the surface**
- **Surface updraft properties from surface layer normal PDF**
- **Stochastic entrainment rate**
- **Prognostic TKE-based ED parameterization**

Latest (shallow + deep) version of EDMF

Updraft/downdraft plume areas are NOT neglected:

i	Convective elements
e	Environment
a_e,a_i	Fractional areas

$$\overline{\varphi} = a_e \varphi_e + \sum_i a_i \varphi_i$$

$$\overline{\varphi'\psi'} = \underbrace{a_e \overline{\varphi'\psi'}|_e}_{\text{ED}} + \underbrace{a_e(\varphi_e - \overline{\varphi})(\psi_e - \overline{\psi})}_{\text{Compensating sub.}} + \underbrace{\cancel{\sum_i a_i \overline{\varphi'\psi'}_i}}_{\text{Sub-plume var.}} + \underbrace{\sum_i a_i(\varphi_i - \overline{\varphi})(\psi_i - \overline{\psi})}_{\text{Multiple MF}}$$

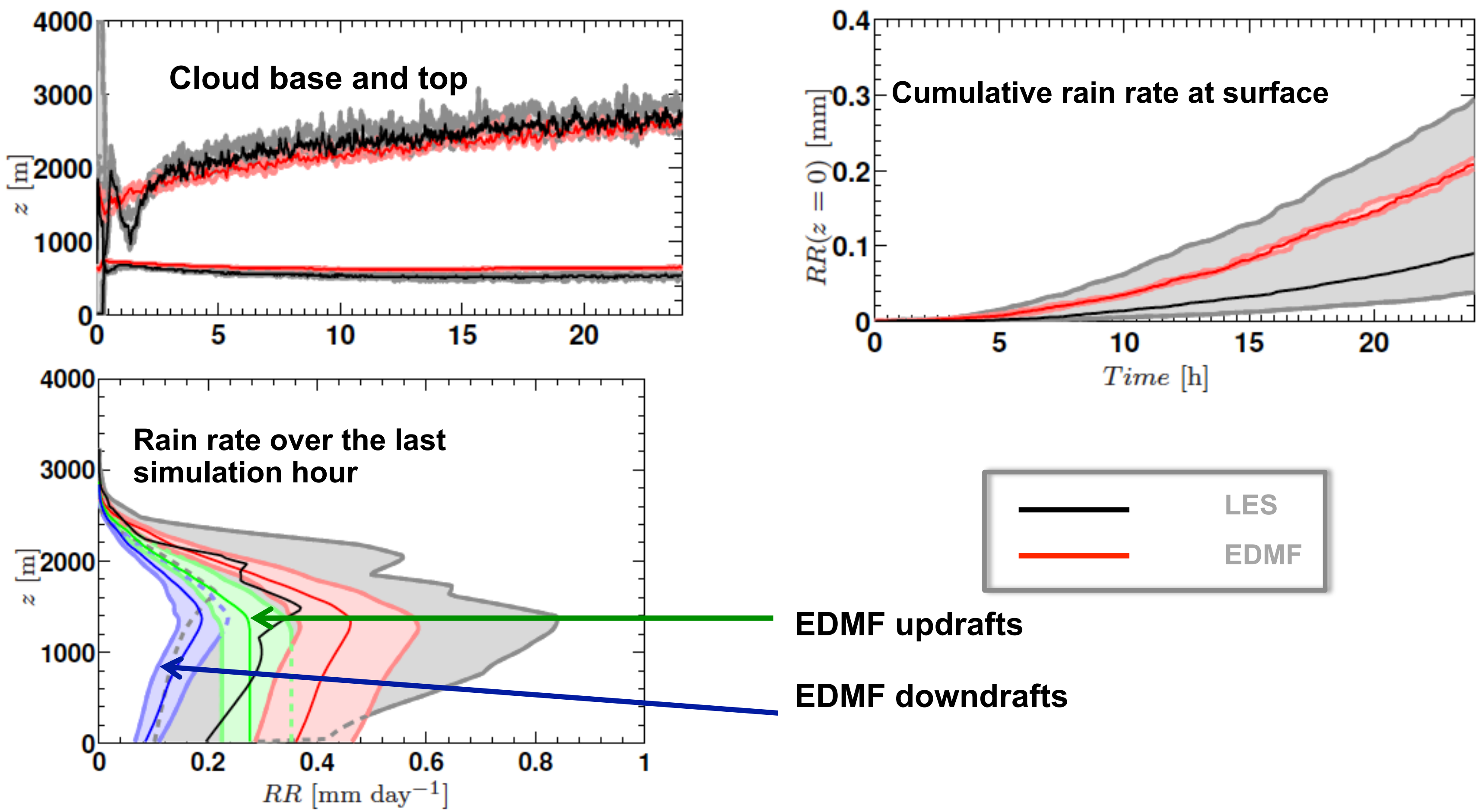
- Simple Kessler-type microphysics coupled to updraft dynamics
- Downdrafts driven by evaporation of rain
- Precipitation-driven cold pools
- Cold pools impact entrainment rates of the updrafts and surface PDF
- PDF cloud macrophysics parameterization

Main advantages:

- **Different types of convection in one grid-box**
- **No need for trigger functions and explicit convective closures**
- **Smooth transition between convective regimes (dry, shallow, deep)**

Precipitating marine convection – RICO case

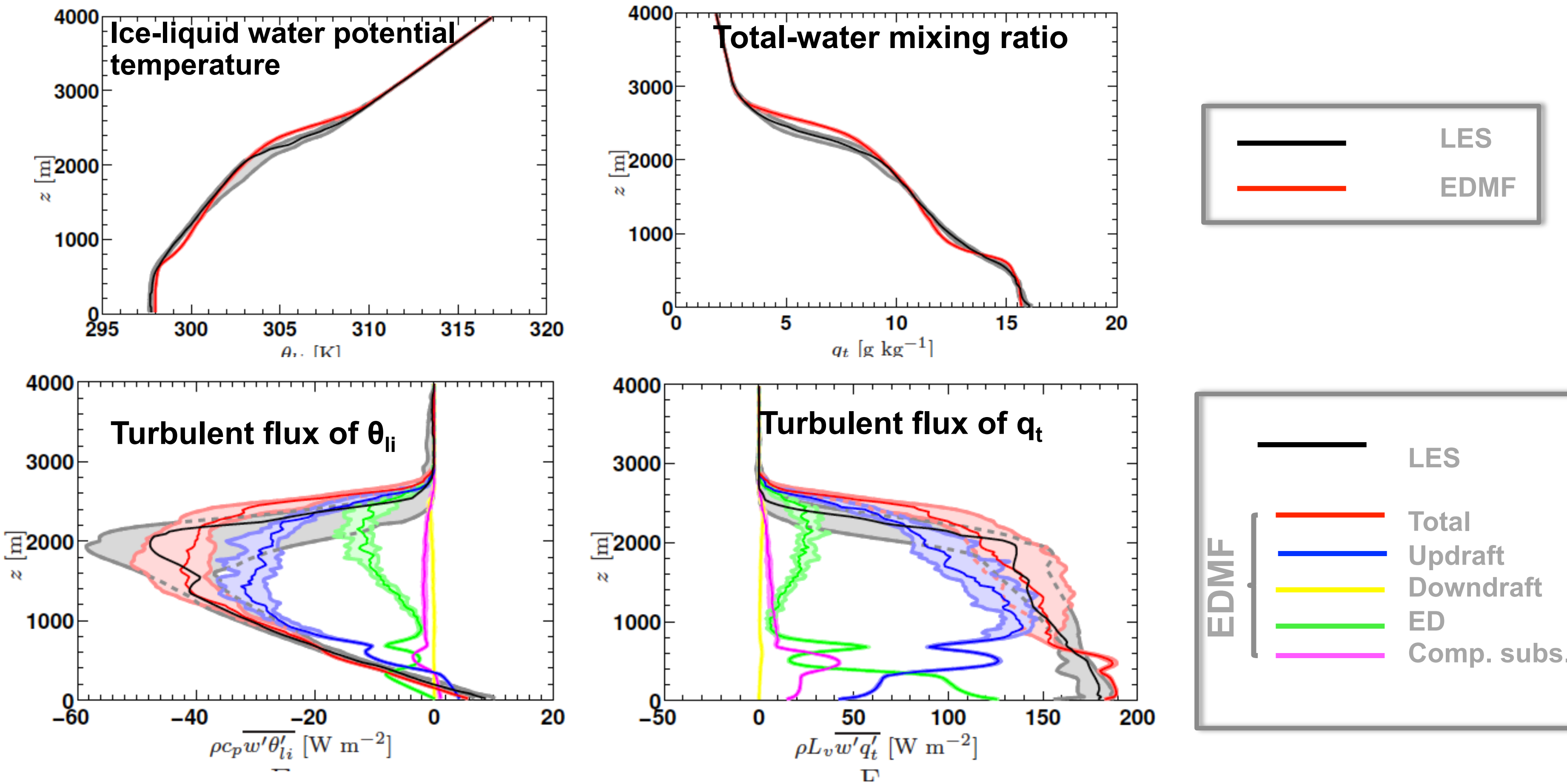
EDMF in SCM vs. against LES from van Zanten et al., (2011)



Precipitating marine convection – RICO case

EDMF in SCM vs. LES from van Zanten et al., (2011)

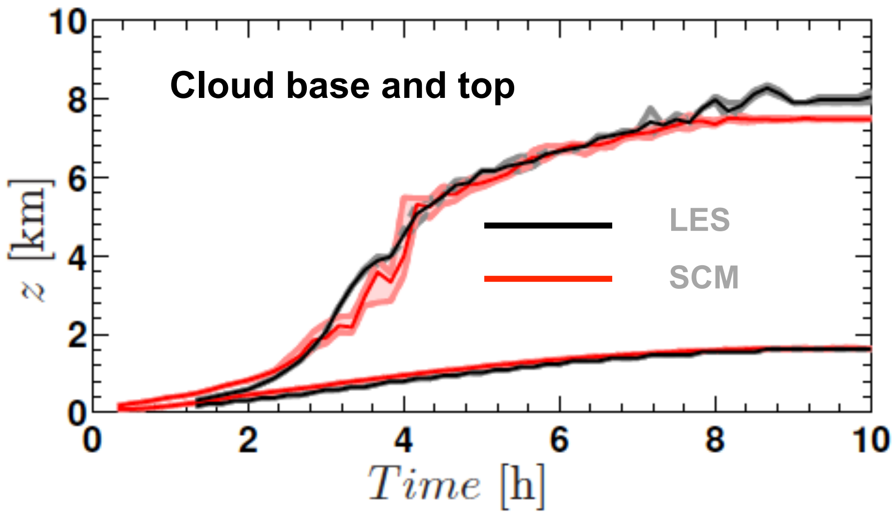
Profiles of moist conserved variables and their turbulent fluxes
(averaged across the 24th simulation hour)

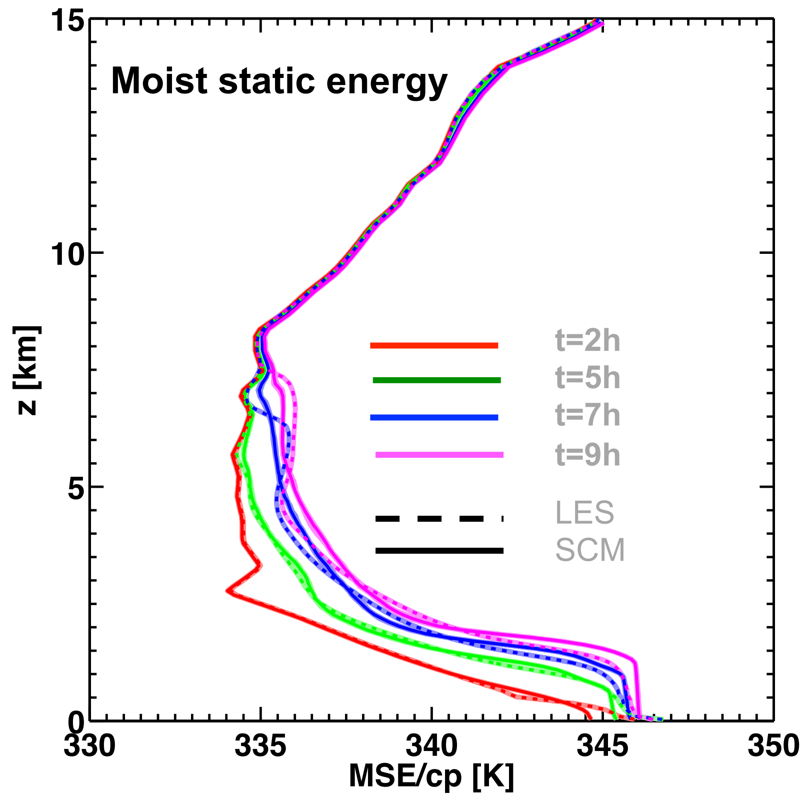


Diurnal cycle of non-precipitating convection

Modified LBA case from Grabowski et al., (2006)

- Without microphysics, condensation with respect to liquid water
- EDMF validation against WRF LES

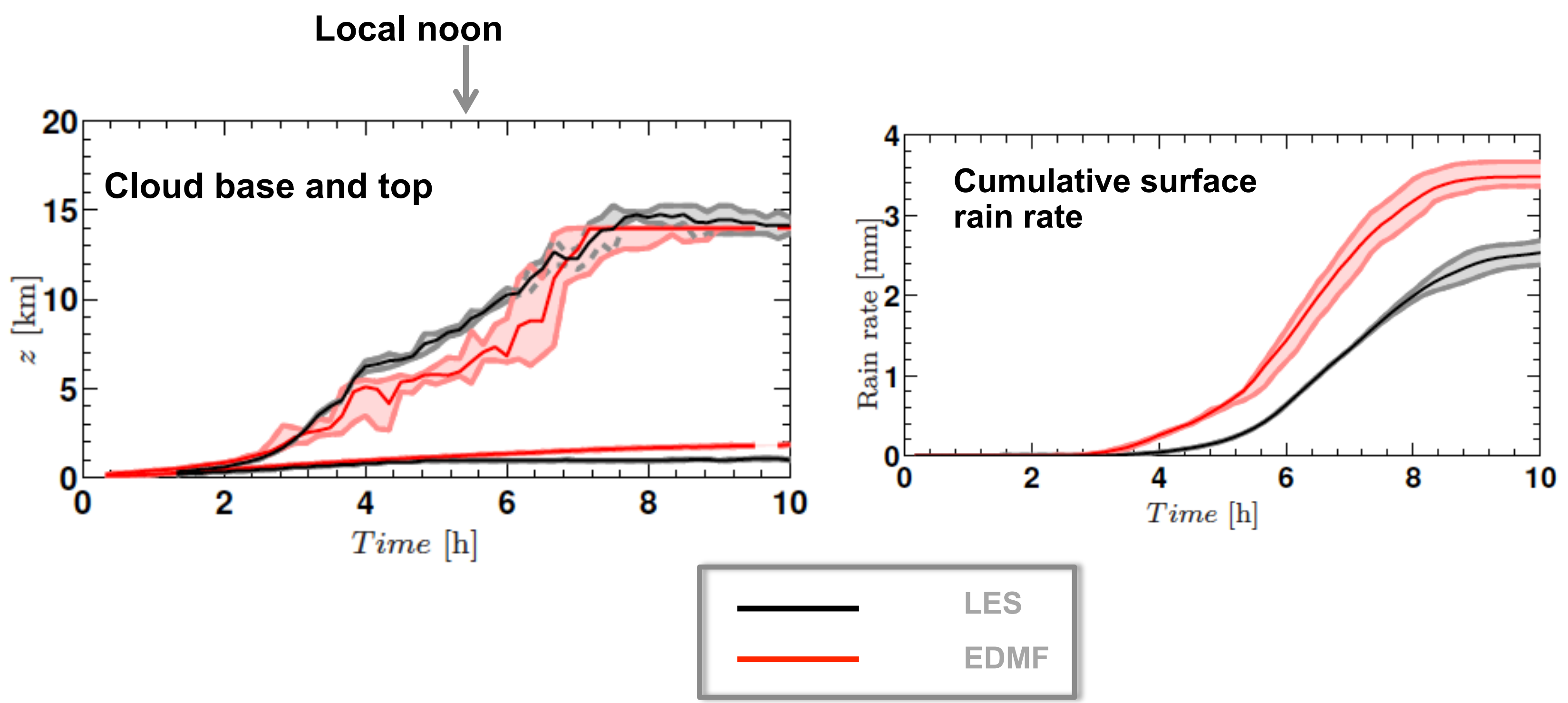




Diurnal cycle of precipitating convection

LBA case from Grabowski et al., (2006)

- Transition from dry convection → non-precipitating shallow → deep precipitating convection
- EDMF validation against WRF LES



Scale dependence for the ED approach

Merging surface layer and the boundary layer:

$$\frac{1}{l} = \frac{1}{l_S} + \frac{1}{l_{BL}}$$

Blackadar (1962)

Merging the 3D and 1D limits:

$$\frac{1}{l_{BL}} = \frac{1}{l_{3D}} + \frac{1}{l_{1D}}$$

New approach

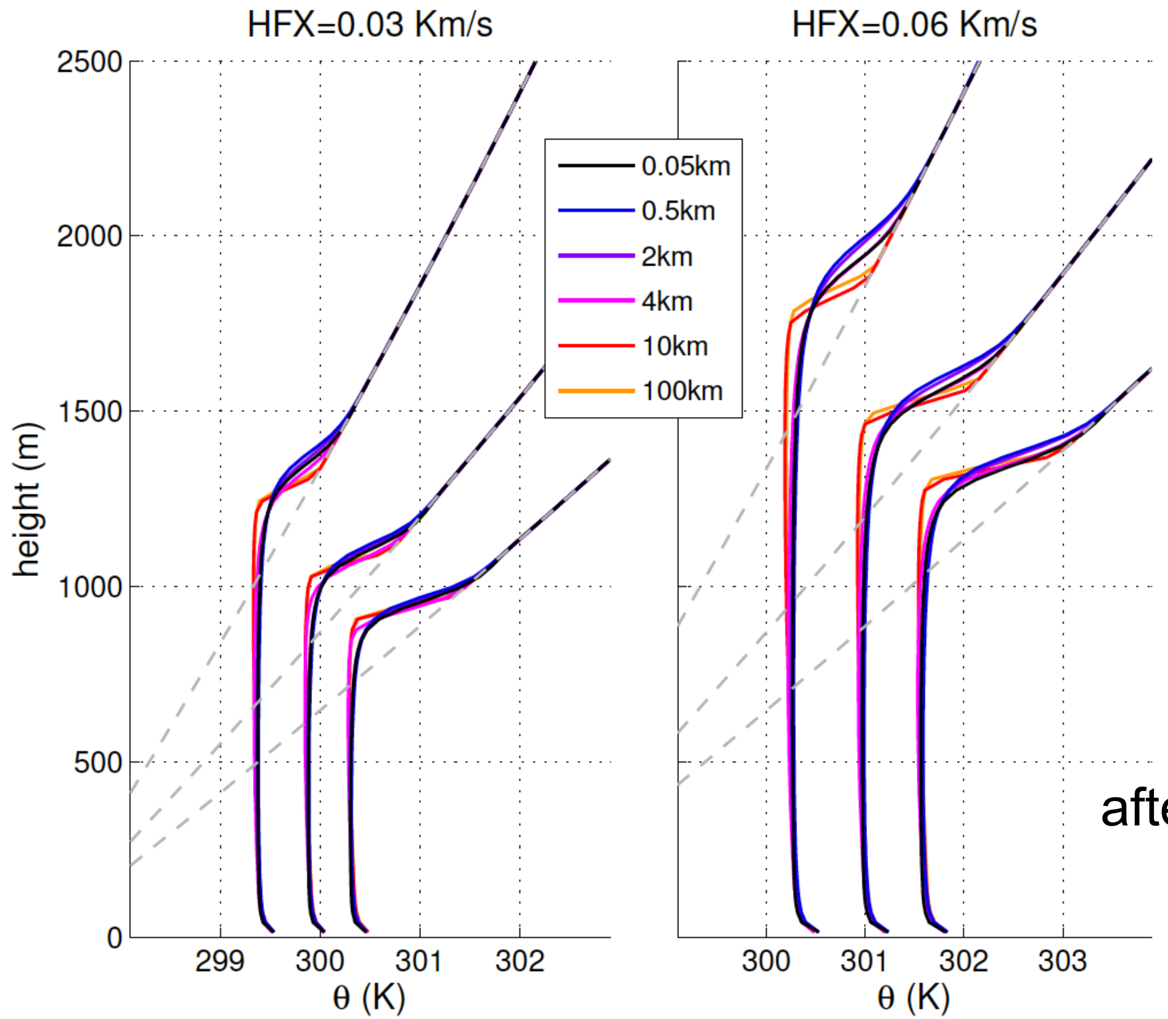
$$l_{3D} = (\Delta x \Delta y \Delta z)^{1/3}.$$

$$l_{1D} = \begin{cases} \lambda & \text{Blackadar (1962)}, \\ \alpha z_i & \text{Grenier and Bretherton (2001)}, \\ \boxed{\tau e^{1/2} \quad \text{Teixeira and Cheinet (2004)}} \ , \end{cases}$$

Dry convective boundary layer
(Siebesma et al. 2007)

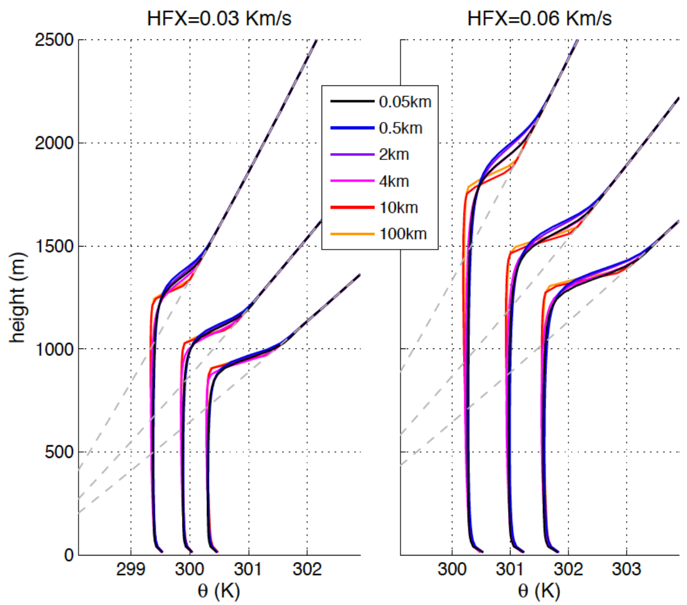
WRF model from LES (Δx=50 m) to NWP/Climate (Δx=100 km)

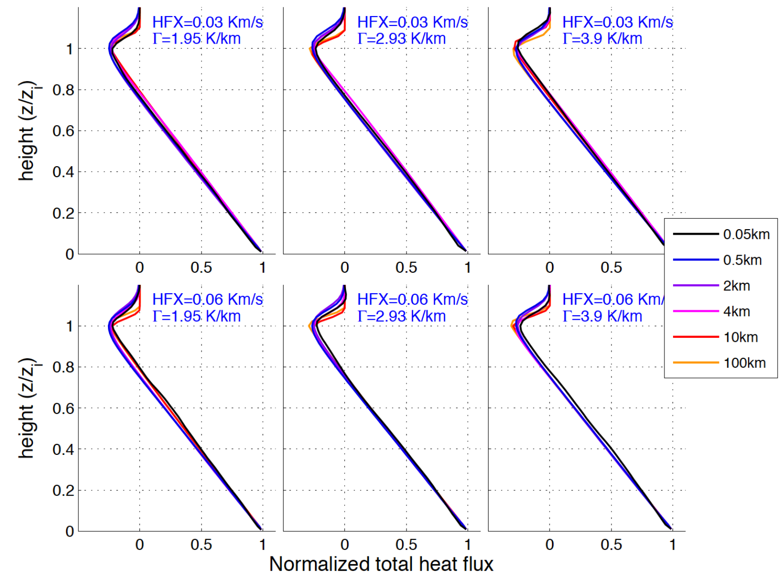
6 cases:
- 3 different stratifications
- 2 different surface heat flux values

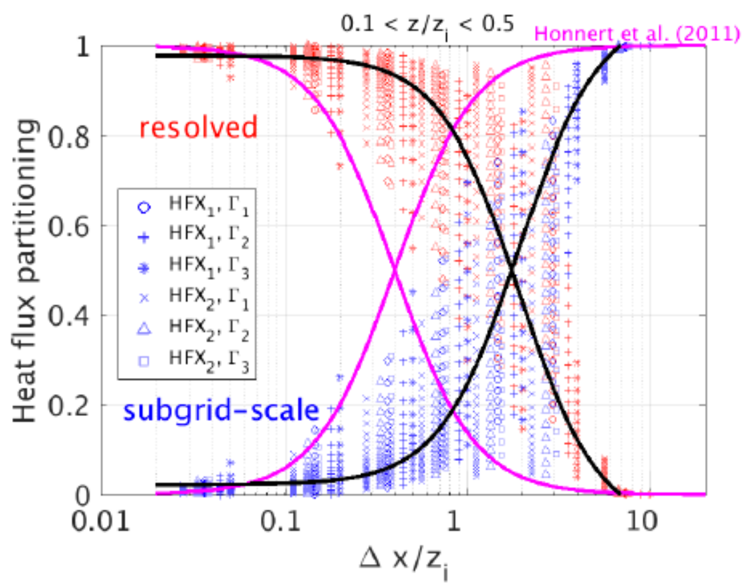


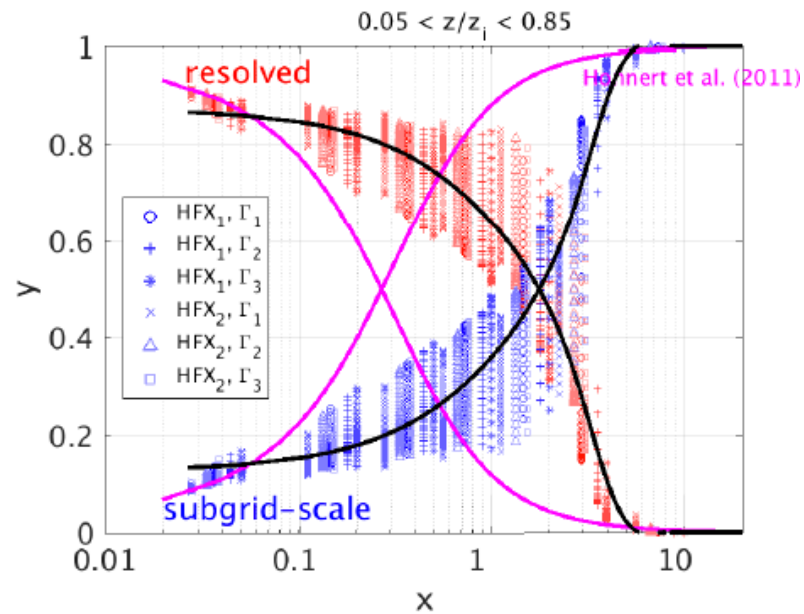
after 10h

Scale dependence for the ED approach









Final thoughts

- **New EDMF parameterization represents boundary layer, dry, shallow and deep precipitating convection in a unified manner**
- **No need for trigger functions and explicit convective closures**
- **Multi-plume approach captures non-linearities arising from interaction between microphysics and dynamics**
- **Work in progress – EDMF parameterization in GEOS-5 GCM:**
    - Initial results - better representation of transition between subtropical stratocumulus to cumulus